Western Lake Erie Basin Expanded Water Quality Monitoring Program

Work Plan

prepared for:
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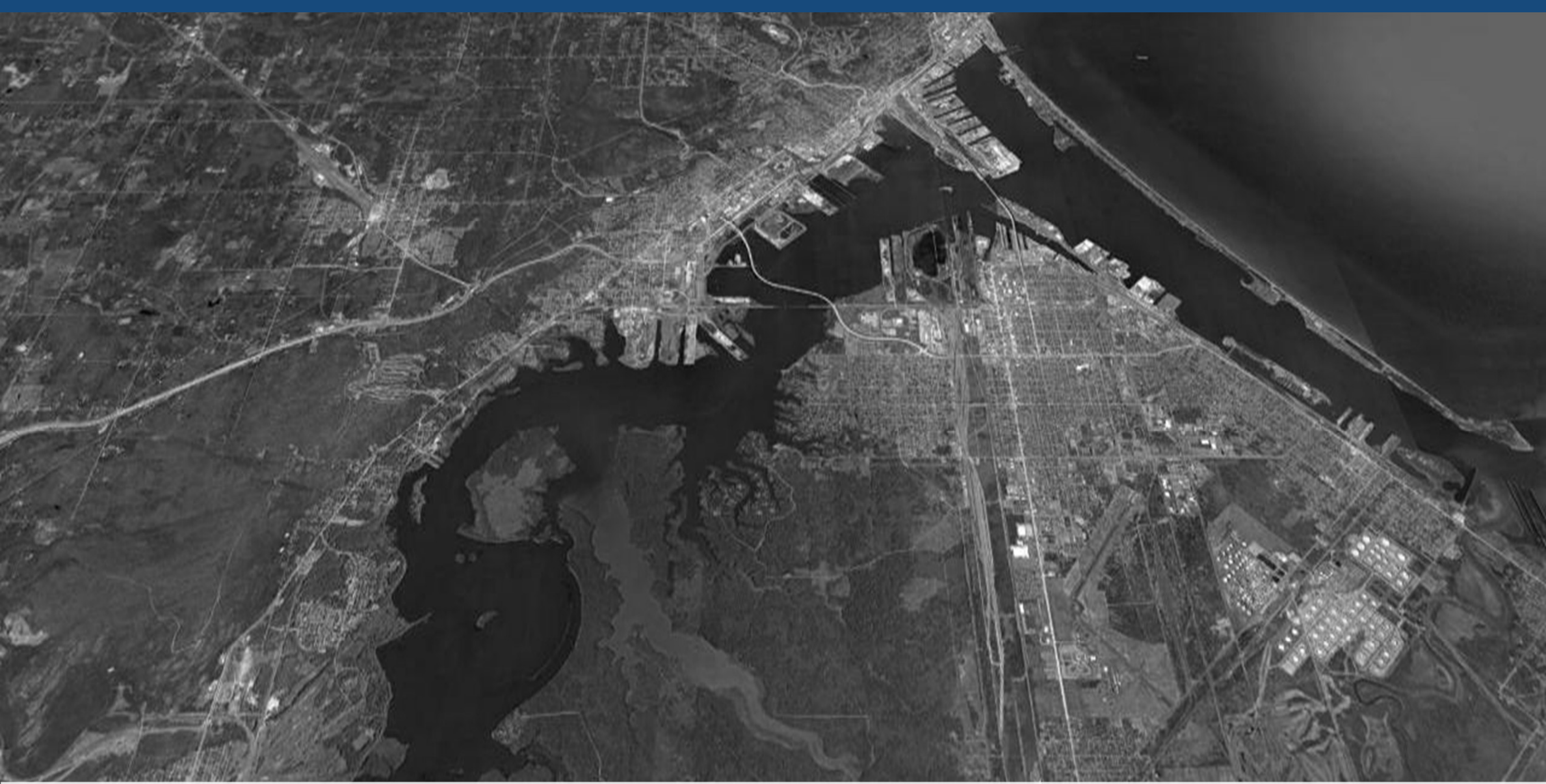
YEAR 1 FINAL

August 12, 2024



LimnoTech
Water Environment | Scientists Engineers

Western Lake Erie Basin Expanded Water Quality Monitoring Program

Work Plan

Year 1 Final

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Executive Summary

Lake Erie experiences chronic harmful algal blooms fueled primarily by excess nutrient loads, particularly phosphorus. Agricultural sources are a primary contributor to phosphorus in the Lake Erie watershed and the main impediment to achieving a 40% reduction in total phosphorus and dissolved reactive phosphorus loading to Lake Erie.

Understanding, tracking, and predicting nutrient loads from sub-watersheds contributing to the basin is difficult due to the complex and variable nature of the drivers of nutrient loss within the various sub-watersheds (weather, cropping systems, farm management, nutrient cycling, etc.) each year. By increasing monitoring capacity, with a particular emphasis on deploying higher spatial density monitoring instrumentation, it would be possible to better understand the impact of various drivers on nutrient transport. For conservation practitioners, the use of higher-density instrumentation will aid in understanding the connection between land management decisions and water quality outcomes. Understanding this connection will allow Agencies and practitioners to better target conservation and land management practices.

To help fill water quality monitoring gaps in the Lake Erie Basin Watershed, the Alliance for the Great Lakes (Alliance) along with partners at Michigan State University Institute for Water Research (IWR) and LimnoTech propose to install water quality monitoring sensors in five Basin sub-watersheds, to include:

- Headwaters of the Saline River (HUC 12- 111401090701)
- S.S. LaPointe Drain (HUC 12- 041000010206)
- Nile Ditch (HUC 12- 041000020303)
- Lime Creek (HUC 12- 041000060105)
- S. Branch River Raisin (HUC 12- 041000020202)

The project team will monitor for nutrients (total phosphorus and dissolved reactive phosphorus) turbidity and total suspended solids. Stream level and precipitation sensors, as well as tile drain monitors will also be installed at strategic locations within the watersheds.

The primary goals of this effort will be **1)** To focus monitoring efforts on understanding three core aspects of each watershed- hydrology, sediment dynamics and phosphorus movement and **2)** To improve Michigan's ability to predict water quality improvements resulting from conservation practices and/or understand the effectiveness of current best management practices (BMPs) and conservation programs for improving water quality parameters.

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1 INTRODUCTION

LimnoTech has prepared this Work Plan for Grant Agreement: 240000002966, Western Lake Erie Basin Expanded Water Quality Monitoring Program. The objective of this work is to better understand hydrology, sediment dynamics and phosphorus movement within (5) sub-watersheds that ultimately drain to Lake Erie. The Project Team will install various water monitoring sensors and sampling equipment, as well as collect manual samples at strategic locations determined at the beginning of the project.

This Work Plan includes information on the following:

- Project Organization and Responsibility.
- Locations and Parameters to be Monitored.
- Monitoring and Sampling Methods & Procedures.
- Data Processing and Management Procedures.
- Quality Control Procedures.
- Data Quality Objectives.
- Reporting Schedule.

In the following pages we have outlined our approach for each of the above-listed components.

2 PROJECT ORGANIZATION AND RESPONSIBILITY

Figure 2-1 contains a project organization chart, which outlines the pathways for reporting between the project contributors.

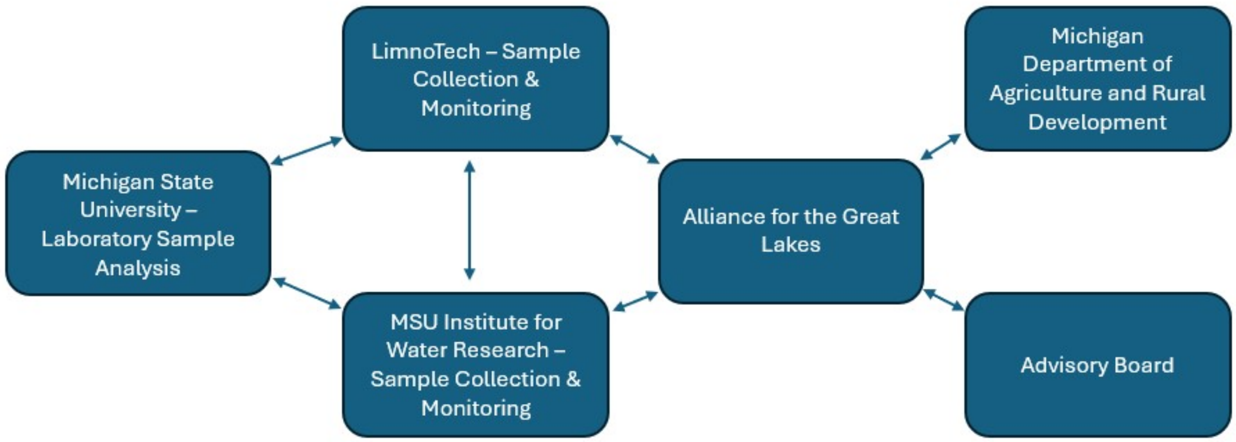

Figure 2-1. Project Organization Chart.

Table 2-1 contains a list of personnel involved in the execution of this Work. Contact information for these personnel is also provided below.

Table 2-1. Personnel, Affiliation and Primary Tasks for the Watershed Monitoring Program.

Personnel	Affiliation	Primary Task(s)
Michelle Selzer	Michigan Department of Agriculture and Rural Development (MDARD)	MDARD Project Manager
Tom Zimnicki	Alliance for the Great Lakes	Alliance Project Manager
Jeremiah Asher	Michigan State University Institute for Water Research (IWR)	IWR Project Manager/QA Officer/Field Coordinator
Ed Verhamme	LimnoTech	LimnoTech Project Manager/QA Officer/Field Coordinator
Chris Behnke	LimnoTech	Sample QA Lead/Field Coordinator/Monitoring
Ken Gibbons	LimnoTech	Sensor Data QA Lead/Monitoring
TBD	Executive Office of the Governor	Project Contact
TBD	Michigan Department of Energy Great Lakes & Environment (EGLE)	Advisory Board- Project Contact
TBD	Michigan Department of Natural Resources (MDNR)	Advisory Board- Project Contact
Ehsan Ghane	MSU Biosystems and Agricultural Engineering Laboratory	Project Contact- Lab QA/QC Supervisor

2.1 MDARD Project Manager

The MDARD Project Manager (Michelle Selzer) is responsible for the implementation of the study and its associated Quality Management Plan (QMP). In addition, the MDARD Project Manager is responsible for:

- Ensuring that an adequate QMP is developed, and that it has been distributed to all appropriate project personnel.
- Ensuring that Standard Operating Procedures (SOPs) included in the QMP, which describe proposed fieldwork methods for the project, are acceptable.

2.2 Alliance for the Great Lakes Project Manager

The Alliance for the Great Lakes Project Manager (Tom Zimnicki) is responsible for the implementation of the study as outlined in the Work Plan. In addition, the Alliance Project Manager is responsible for:

- Coordinating / communicating problems with the MDARD Project Manager and/or other Project Managers over the course of the project.
- Overall supervision/management with respect to project tasks.
- Initiating corrective actions, as necessary.
- Reviewing reports for accuracy, precision, completeness, and representativeness.
- Ensuring that that the Work Plan has been distributed to and acknowledged by all appropriate project personnel.

2.3 Institute for Water Research Project Manager / QA Officer / Field Coordinator

The IWR Project Manager / QA Officer / Field Coordinator (Jeremiah Asher) is responsible for the implementation of the IWR portion of the study as outlined in the Work Plan. In addition, the IWR Project Manager is responsible for:

- Coordinating / communicating problems with the Alliance & LimnoTech Project Managers over the course of the project.
- Overall project management with respect to IWR tasks.
- Ensuring that all QA/Quality Control (QC) requirements are followed for IWR related sampling, data monitoring and laboratory activities.
- Initiating corrective actions, as necessary.
- Ensuring that the IWR SOPs are followed, or that deviations are documented and explained.
- Reviewing reports for accuracy, precision, completeness, and representativeness.

2.4 LimnoTech Project Manager / QA Officer

The LimnoTech Project Manager / QA Officer (Ed Verhamme) is responsible for the implementation of the LimnoTech portion of the study as outlined in the Work Plan. In addition, the LimnoTech Project Manager / QA Officer is responsible for:

- Coordinating / communicating problems with the Alliance Project Manager and IWR Project Managers over the course of the project.
- Overall project management with respect to LimnoTech tasks.
- Ensuring that all QA/Quality Control (QC) procedures are followed for LimnoTech related sampling, data monitoring and laboratory activities, or that deviations are documented and explained.
- Initiating corrective actions, as necessary.
- Reviewing reports for accuracy, precision, completeness, and representativeness.

2.5 LimnoTech Sampling Lead

The LimnoTech Sampling Lead (Chris Behnke) is responsible for implementation of sample collection objectives as outlined in the Work Plan. In addition, the LimnoTech Sampling Lead is responsible for:

- Ensuring that all Quality Control procedures are followed for sampling and laboratory activities.
- Reviewing analytical results received from the laboratory.
- Relaying all related issues to the LimnoTech Project Manager.

2.6 LimnoTech Monitoring Data Lead

The LimnoTech Monitoring Data Lead (Ken Gibbons) is responsible for meeting the monitoring / sensor data objectives as outlined in the Work Plan. In addition, the Monitoring Data Lead is responsible for:

- Ensuring that all Quality Control procedures are followed for remote monitoring activities (i.e.- sensor accuracy & precision).
- Monitoring the sensor network for data anomalies and initiating investigative and/or corrective measures.
- Relaying all related issues to the LimnoTech Project Manager.

2.7 LimnoTech Field Coordinators

The LimnoTech Field Coordinators for this project are Ed Verhamme and Chris Behnke. They are responsible for ensuring that the sample collection, monitoring equipment maintenance and transport activities are conducted in a manner that provides confidence in the resulting data. Specifically, they will be responsible for the following:

- Organizing equipment, staff, and materials for field activities.
- The Initiation of sampling events to correspond with appropriate runoff conditions.
- Ensuring that all staff are correctly and safely operating the sampling / monitoring equipment.
- Managing the day-to-day field sampling/monitoring activities to ensure that field procedures conform to the requirements outlined in the applicable SOPs.
- Resolving day-to-day problems with respect to the implementation of the study.
- Reviewing field generated records and data for accuracy, validity, and completeness.

2.8 Monitoring/Field Staff

IWR and LimnoTech staff conducting fieldwork will coordinate with appropriate laboratory staff to avoid the possibility of exceeding sample holding times. In addition, the Field staff are responsible for the day-to-day monitoring, sample collection and drop-off activities. Project Managers are responsible for training Field Staff, as necessary. Specifically, they will have the following responsibilities:

- Collecting water samples and in-situ parameters.
- Periodically delivering the water samples to the analytical laboratory.
- Notifying managers of necessary site/equipment maintenance.
- Performing any necessary site / equipment maintenance.
- Maintaining field notebooks and/or logs.

2.9 Laboratory QA/QC Supervisor

The Supervisor for MSU Laboratory (Ehsan Ghane). He is responsible for ensuring that the samples are analyzed and reported according to the protocols outlined in this Work Plan and applicable SOPs. In addition, the MSU Laboratory Supervisor is responsible for:

- Notifying project personnel (Monitoring staff and/or Sampling Lead) of any issues or limitations that could affect the acceptance and/or analysis of project samples. (i.e.- lab staffing, schedule, etc.)

Table 2-2 provides a contact list for project personnel.

Table 2-2. Project Contact List.

Personnel		Email	Phone Number
Michelle Selzer	Michigan Department of Agriculture and Urban Development	selzerm@michigan.gov	517-599-3073
Tom Zimnicki	Alliance For the Great Lakes	tzimnicki@greatlakes.org	313-969-3499
Jeremiah Asher	Michigan State University	asherjer@msu.edu	517-432-5586
Ed Verhamme	LimnoTech	everhamme@limno.com	734-681-0577
Chris Behnke	LimnoTech	cbehnke@limno.com	734-673-2209
Ken Gibbons	LimnoTech	kgibbons@limno.com	734-821-3144
Ehsan Ghane	Michigan State University	ghane@msu.edu	

3 SUB-WATERSHED MONITORING

3.1 Monitoring Locations

As previously stated, monitoring will be conducted over a 5-year period at various locations in connection with five priority HUC-12 sub-watersheds that ultimately drain to Lake Erie. Monitoring locations within each sub-watershed were selected based on the percent of the drainage area captured as well as considerations with respect to safe site access during monitoring and maintenance activities. A small number of locations were also selected outside the boundaries of the five sub-watersheds to better understand more regional inputs. Staff from MDARD, EGLE, DNR and county conservation districts reviewed and approved all monitoring site locations. Where applicable, permits will be obtained prior to equipment installation.

It is anticipated that monitoring equipment will be installed and operating at all locations by October 1st, 2024. Monitoring may be truncated at any or all the sites at the MDARD Project Manager's discretion at any time, with prior notice to the rest of the Project Team. Monitoring locations may be added, removed, or re-located over the course of the project at the discretion of the Project Team. Figure 3-1 shows the locations to be monitored over the course of the project. The following sections present details with respect to each priority sub-watershed.

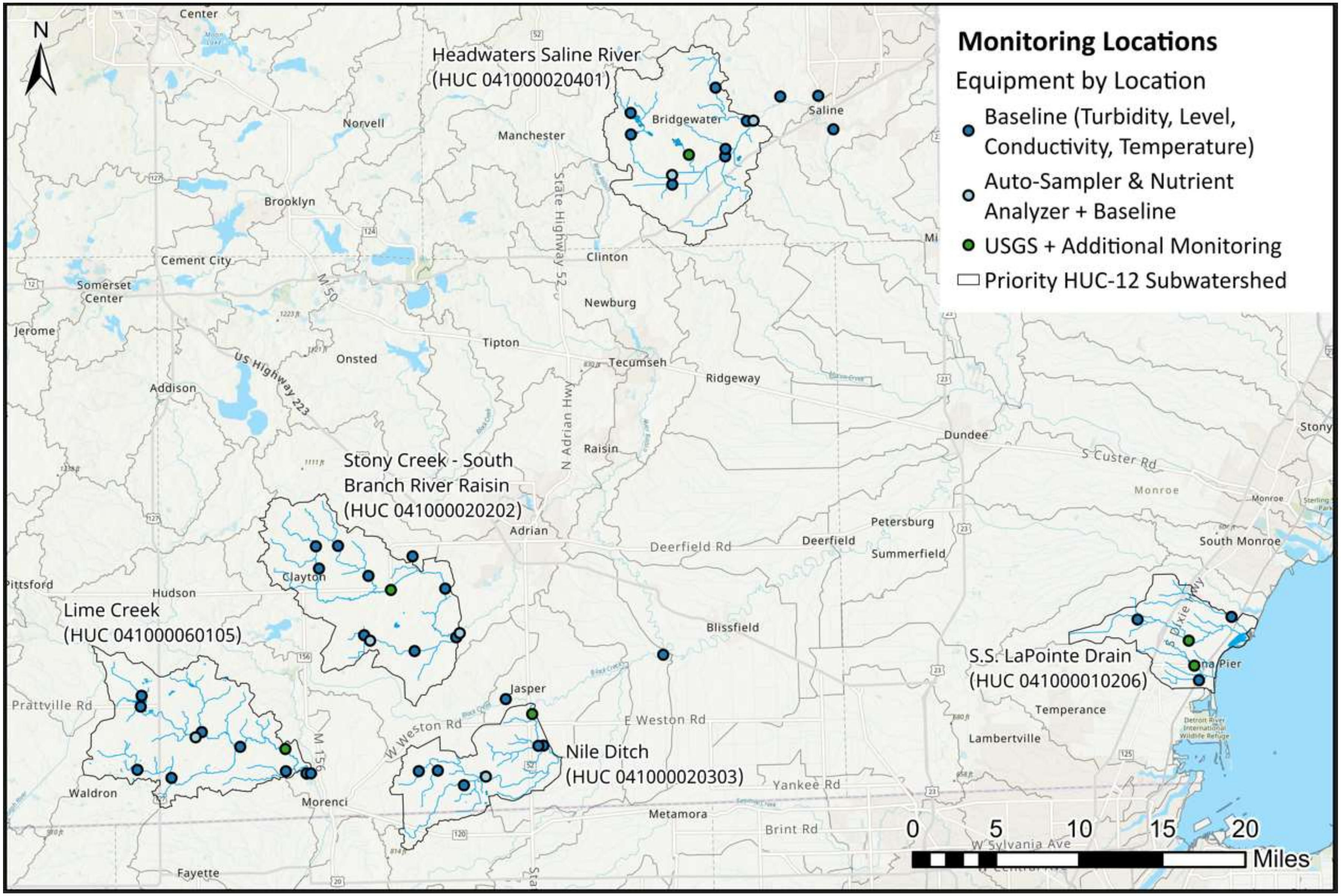

Figure 3-1. All Sub-watershed Monitoring Locations.

3.2 Saline River Headwaters Locations (HUC 12- 111401090701)

The Saline River sub-watershed incorporates a mix of agricultural and suburban land use and includes several impoundments which will provide valuable comparative information with other sub-watersheds in the Basin. The Saline River also offers a unique opportunity as it has a permanent USGS water monitoring station located near the outlet of the watershed and a planned USGS station in the upper reaches of the watershed.

Table 3-1 lists locations to be monitored in the Saline River sub-watershed, with sensors and equipment to be utilized at specific locations.

ID #	Location Description	Latitude	Longitude	Water Level	Turbidity	Conductivity	Temperature	Nutrient Analyzer (TP)	Auto-Sampler	USGS Water Level & Flow
SR-1	Saline River @ E. Austin Rd.	42.152084	-83.95111	X	X	X	X			
SR-2	Saline River @ McCollum Rd.	42.126010	-83.91528	X	X	X	X	X	X	
SR-3	Unnamed Drain @ McCollum Rd.	42.119878	-83.91516	X	X	X	X			
SR-4	Unnamed Drain (south) near Feldkamp Rd.	42.137944	-83.86909	X	X	X	X			
SR-5	Unnamed Drain (north) @ Feldkamp Rd.	42.142837	-83.86888	X	X	X	X			
SR-6	Unnamed Drain @ Bethel Church Rd.	42.182261	-83.87753	X	X	X	X			
SR-7	Unnamed Drain @ Austin Rd.	42.160804	-83.85025	X	X	X	X			
SR-8	Saline River @ Austin Rd.	42.160999	-83.84448		X	X	X	X	X	X
SR-9	Unnamed Drain (west) @ Saline Waterworks Rd.	42.176538	-83.82125	X	X	X	X			
SR-10	Koch Warner Drain @ Saline Milan Rd.	42.155914	-83.77485	X	X	X	X			
SR-11	Unnamed Drain (east) @ Saline Waterworks Rd.	42.177161	-83.78855	X	X	X	X			
SR-12	Joslin Lake Outlet @ Burmeister Rd.	42.139040	-83.90065	X	X	X	X			
SR-13	Columbia Lake Inlet @ Bemis Rd.	42.166017	-83.95131	X	X	X	X			

Table 3-1. Saline River Headwaters Monitoring Locations.

Figure 3-2 displays the monitoring locations in (and associated with) the Saline River sub-watershed.

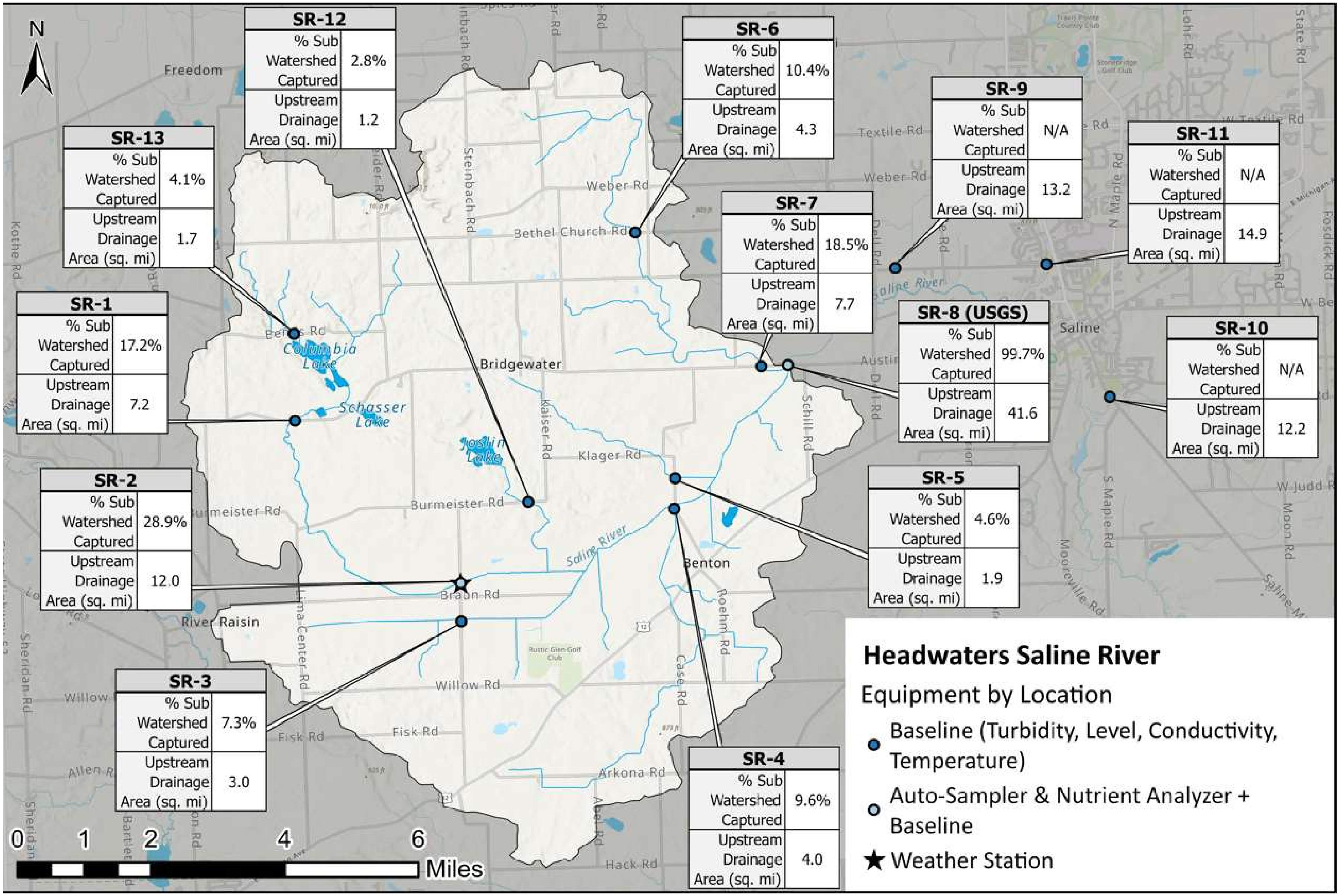

Figure 3-2. Saline River Sub-Watershed Monitoring Location.

3.3 Nile Ditch Sub-Watershed Locations (HUC 12- 041000010206)

The Nile Ditch sub-watershed exhibits flatter terrain than the Saline River sub-watershed and is dominated by cropland with minimally developed wetland acres. It also has a greater density of tile-drained acres and channelized surface ditches. This sub-watershed has a greater density of livestock operations and manure application and will provide an opportunity to better understand how these various landscape differences impact stream hydrology and water quality dynamics.

Table 3-2 lists locations to be monitored in the Nile Ditch sub-watershed, with sensors and equipment to be utilized at specific locations.

Table 3-2. Nile Ditch Sub Watershed Locations.

ID #	Location Description	Latitude	Longitude	Water Level	Turbidity	Conductivity	Temperature	Nutrient Analyzer (TP)	Auto-Sampler	USGS Water Level & Flow
ND-1	Nile Ditch @ Arnold Rd.	41.77761	-84.03689		X	X	X	X	X	X
ND-2	Raymond Drain / Niles Ditch @ E. Ridgeville Rd.	41.75711	-84.02719	X	X	X	X			
ND-3	Nile Ditch @ Lyons Hwy.	41.73703	-84.07723	X	X	X	X	X	X	
ND-4	Unnamed Drain @ W. Mulberry Rd.	41.74055	-84.13554	X	X	X	X			
ND-5	Black Creek @ S. Adrian Hwy. (M-52)	41.78615	-84.04041	X	X	X	X			
ND-6	Knapp Drain @ E. Ridgeville Rd.	41.75699	-84.03155	X	X	X	X			
ND-7	Unnamed Drain @ W. Mulberry Rd.	41.7406	-84.11922	X	X	X	X			
ND-8	Black Creek @ Crockett Hwy.	41.81607	-83.92297	X	X	X	X			
ND-9	Unnamed Drain @ Sand Creek Hwy.	41.73144	-84.09628	X	X	X	X			

Figure 3-3 displays the monitoring locations in (and associated with) the Nile Ditch sub-watershed.

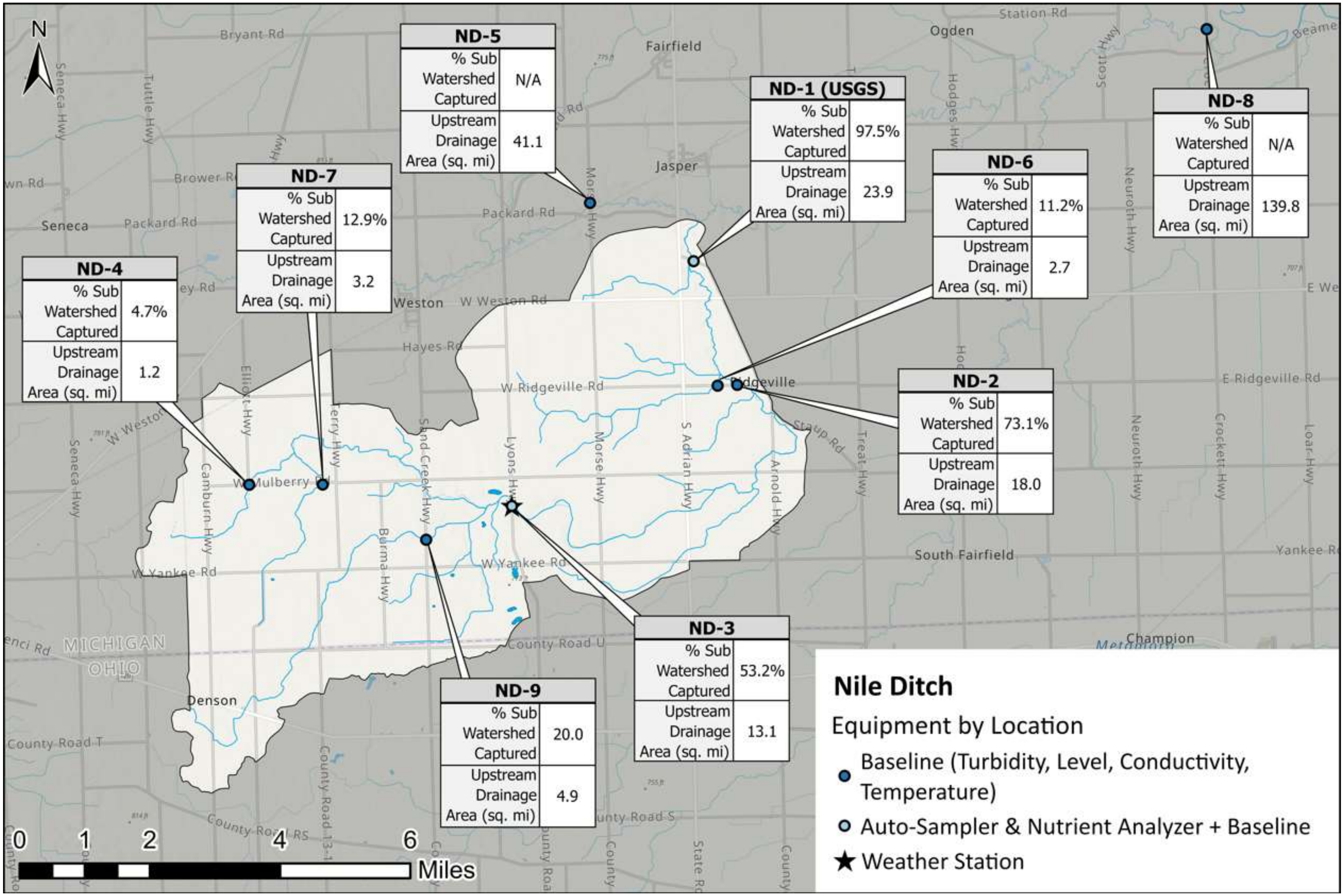

Figure 3-3. Nile Ditch Sub-Watershed Monitoring Locations.

3.4 Lime Creek Locations (HUC 12- 041000060105)

Agricultural land use dominates the Lime Creek sub-watershed, with a majority of this farmland being heavily tiled for maximum drainage. Animal wastes are generally sprayed or injected on the land throughout the watershed, increasing the likelihood in this area for phosphorus runoff to creeks and tributaries.

Table 3-3 lists locations to be monitored in the Lime Creek sub-watershed, with sensors and equipment to be utilized at specific locations.

Table 3-3. Lime Creek Sub Watershed Locations.

ID #	Location Description	Latitude	Longitude	Water Level	Turbidity	Conductivity	Temperature	Nutrient Analyzer (TP)	Auto-Sampler	USGS Water Level & Flow
LC-1	Lime Creek @ Ranger Hwy.	41.7549	-84.25159		X	X	X	X	X	X
LC-2	Toad Creek @ Ingall Hwy.	41.75633	-84.29084	X	X	X	X			
LC-3	Lime Creek @ Ingall Hwy.	41.76255	-84.32959	X	X	X	X	X	X	
LC-4	Lime Lake Outlet @ Prattville Rd.	41.7824	-84.37734	X	X	X	X			
LC-5	Lime Creek @ W. Mulberry Rd.	41.7391	-84.2332	X	X	X	X			
LC-6	Bean Creek @ W. Mulberry Rd.	41.73909	-84.22939	X	X	X	X			
LC-7	Toad Creek @ W. Mulberry Rd.	41.73619	-84.35058	X	X	X	X			
LC-8	Lime Lake Inlet @ Lime Lake Rd.	41.78912	-84.37673	X	X	X	X			
LC-9	Mansfield Creek @ Ranger Hwy.	41.74088	-84.25125	X	X	X	X			
LC-10	Toad Creek @ Seeley Rd.	41.74143	-84.38021	X	X	X	X			
LC-11	Unnamed Drain @ Lime Creek Rd.	41.76588	-84.32424	X	X	X	X			

Figure 3-4 displays the monitoring locations in (and associated with) the Lime Creek sub-watershed.

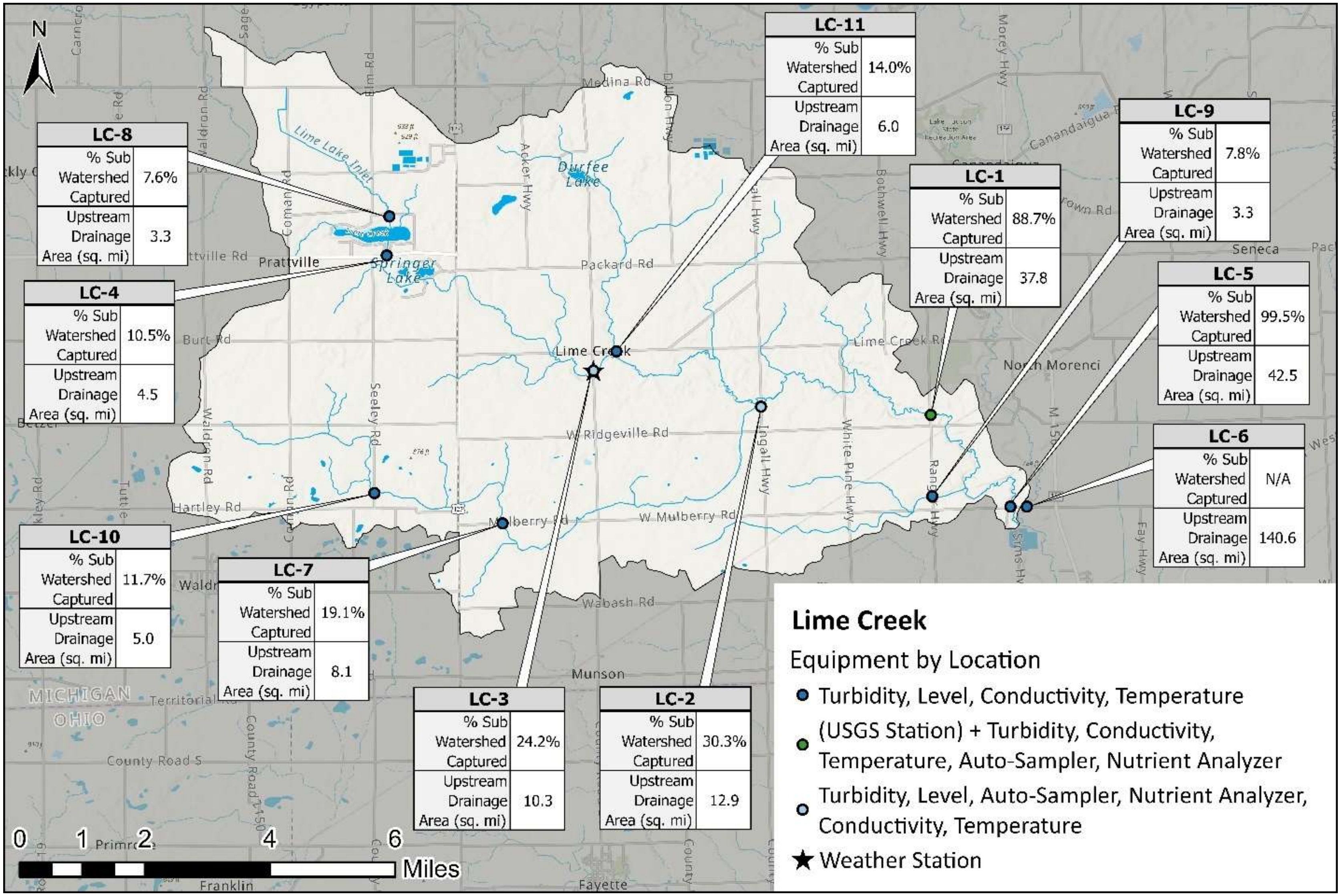

Figure 3-4. Lime Creek Sub-Watershed Monitoring Locations.

3.5 Stony Creek / South Branch River Raisin Locations (HUC 12- 041000020202)

The Stony Creek (South Branch River Raisin) subwatershed covers nearly 46 square miles. This subwatershed is made up mostly of rural cropland with a few towns and villages throughout. The largest of these is the village of Clayton. About 70% of the total land used is made up of farm fields, roughly totaling 20,700 acres. (U of M, MDARD, 2024)

Table 3-4 lists locations to be monitored in the Stony Creek / South Branch River Raisin sub-watershed, with sensors and equipment to be utilized at specific locations.

Table 3-4. Stony Creek / South Branch River Raisin Sub Watershed Locations.

ID #	Location Description	Latitude	Longitude	Water Level	Turbidity	Conductivity	Temperature	Nutrient Analyzer (TP)	Auto-Sampler	USGS Water Level & Flow
SBR-1	S. Br. River Raisin @ Benner Hwy.	41.857831	-84.15964		X	X	X	X	X	X
SBR-2	Harrison Drain @ Beecher Rd.	41.886462	-84.20577	X	X	X	X			
SBR-3	S. Branch River Raisin @ Cadmus Rd.	41.871791	-84.22229	X	X	X	X			
SBR-4	Hazen Creek @ Sword Hwy.	41.879749	-84.14091	X	X	X	X			
SBR-5	Stony Creek @ Sword Hwy.	41.818416	-84.13924	X	X	X	X			
SBR-6	Harrison Drain @ Seneca Hwy.	41.867082	-84.17927	X	X	X	X			
SBR-7	S. Br. River Raisin @ Sand Creek Hwy.	41.830007	-84.09967	X	X	X	X	X	X	
SBR-8	Unnamed Drain @ Livesay Rd.	41.827379	-84.10331	X	X	X	X			
SBR-9	Stony Creek @ Seneca Hwy.	41.825108	-84.17789	X	X	X	X	X	X	
SBR-10	Bovee Drain @ Haley Rd.	41.828654	-84.18306	X	X	X	X			
SBR-11	S. Br. River Raisin @ W. Carleton Rd.	41.858833	-84.11256	X	X	X	X			
SBR-12	S. Br. River Raisin @ Beecher Rd.	41.886198	-84.22497	X	X	X	X			

Figure 3-5 displays the monitoring locations in (and associated with) the Stony Creek / South Branch River Raisin sub-watershed.

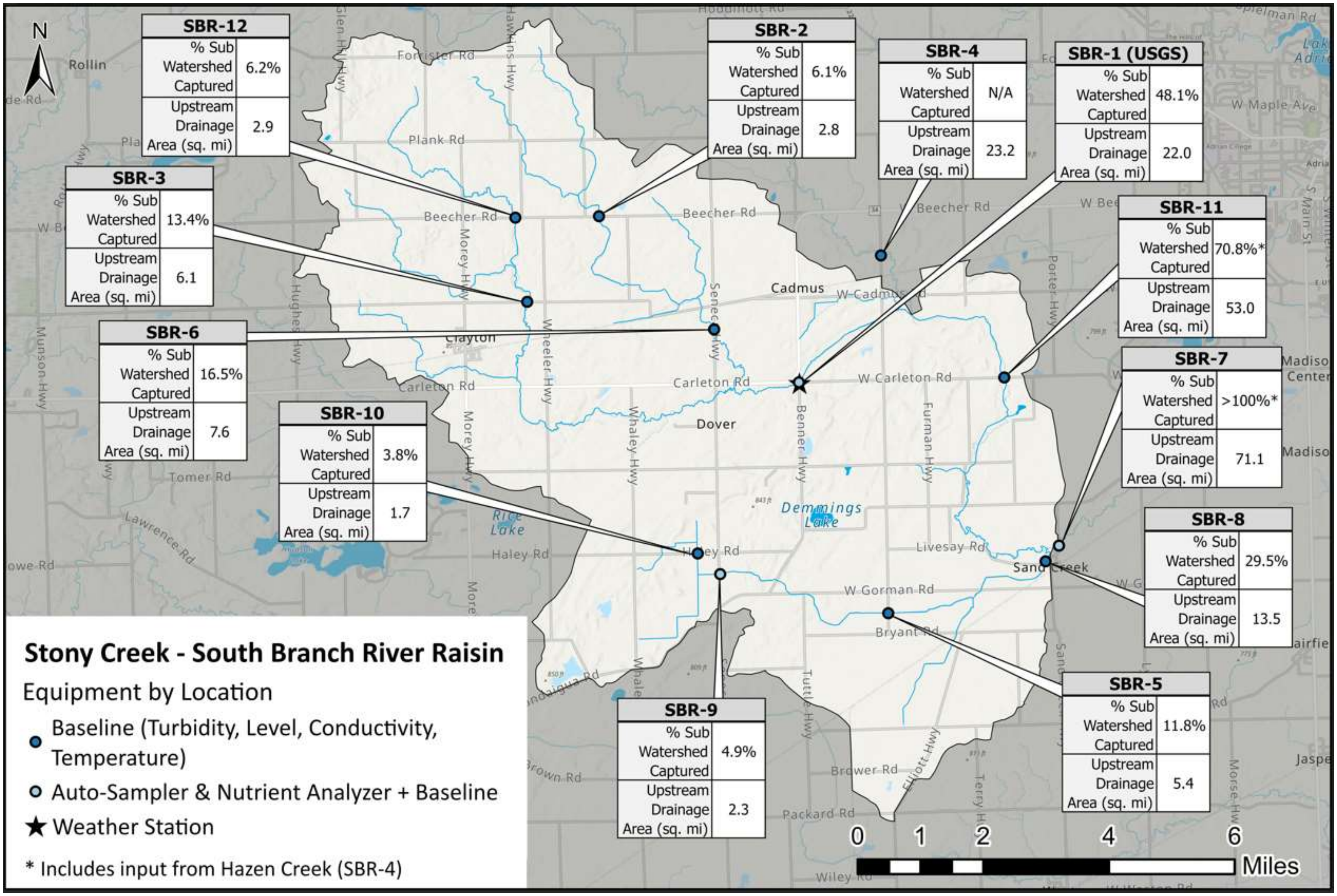

Figure 3-5. Stony Creek / South Branch River Raisin Sub-Watershed Monitoring Locations.

3.6 S.S. Lapointe Drain Locations (HUC 12- 041000010206)

One of the five sub-watersheds included in this study is S.S. Lapointe, located near to the Lake Erie shoreline, flowing directly to the lake. In comparison to other priority sub-watersheds included in this study, S. S. Lapointe is generally flatter in elevation. Also, depending on the wind direction, intensity and local runoff conditions, the influence of Lake Erie can extend up into this subwatershed. Table 3-5 lists locations to be monitored that include Sulphur, Whitewood and Muddy Creeks, with sensors and equipment to be utilized at specific locations.

Table 3-5. S. S. Lapointe Sub Watershed Locations.

ID #	Location Description	Latitude	Longitude	Water Level	Turbidity	Conductivity	Temperature	Nutrient Analyzer (TP)	Auto-Sampler	USGS Water Level & Flow
SSL-1	Sulphur Creek @ Cousino Rd.	41.84053	-83.42884	X	X	X	X			
SSL-2	Muddy Creek @ Belleterre St.	41.82511	-83.466		X	X	X	X	X	X
SSL-3	Unnamed Drain @ Grodi Rd.	41.79946	-83.45718	X	X	X	X			
SSL-4	Muddy Creek @ Wood Rd.	41.8388	-83.51054	X	X	X	X			
SSL-5	Whitewood Creek @ Luna Pier Rd.	41.80891	-83.4612		X	X	X			X

Figure 3-6 displays the monitoring locations in (and associated with) the S. S. Lapointe Drain sub-watershed.

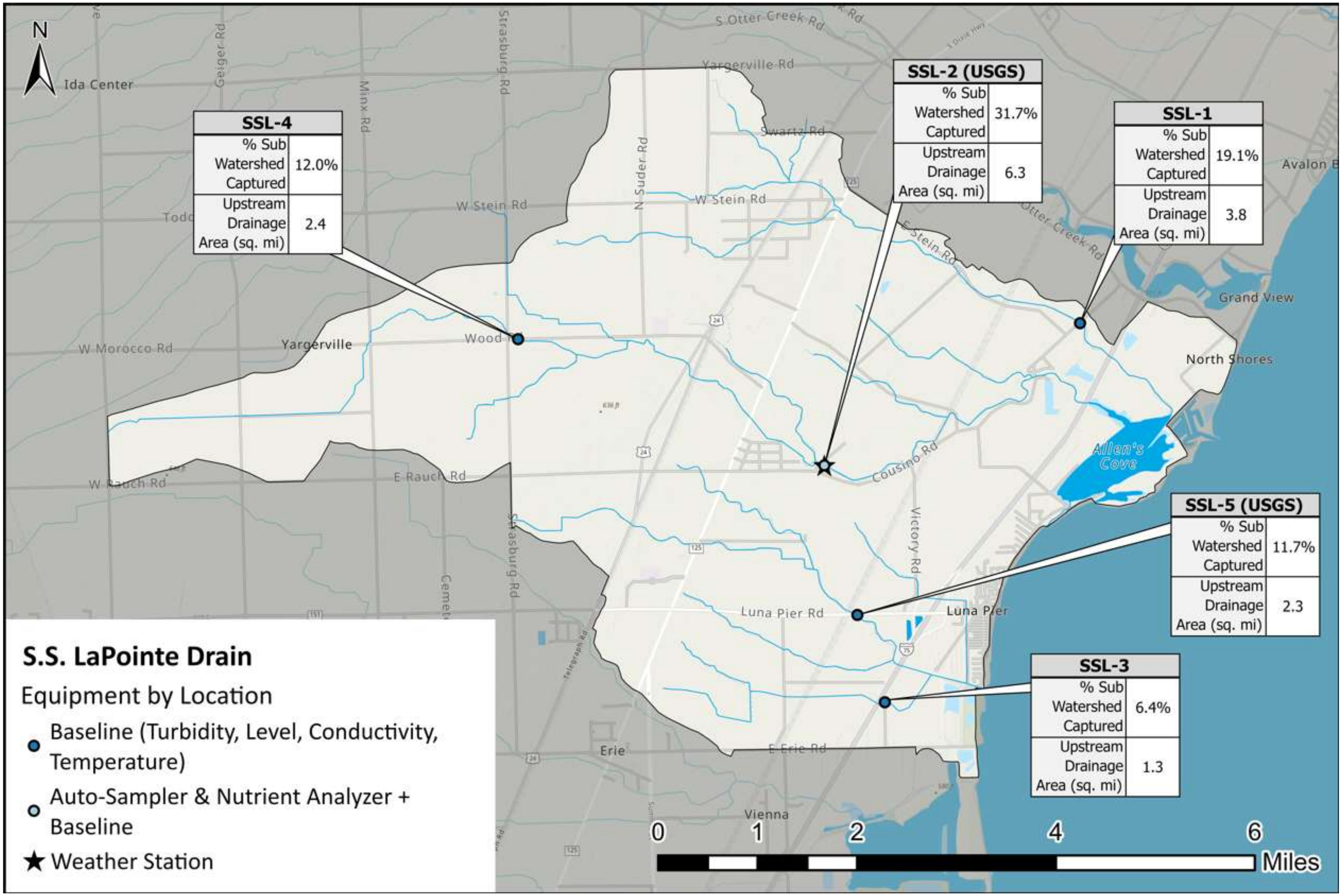

Figure 3-6. S.S. Lapointe Sub-Watershed Monitoring Locations.

4 MONITORING METHODS- SENSORS

4.1 Sensor Installations- Road Crossings

Locations will be monitored using locally installed sensors that report collected data to an online dashboard via cellular connection. All locations will measure level, turbidity, conductivity and water temperature. Equipment will be installed at each location in a manner that optimizes access to the thalweg and protection from upstream debris, if feasible. Some monitoring will occur at existing USGS locations, where level and flow monitoring is already being conducted. At these locations, redundant level monitoring will not occur. Once equipment is installed, final GPS coordinates will be obtained. Atmospheric monitoring will occur at (1) location within each HUC-12 priority sub watershed. Table 4-1 outlines the data to be collected, as well as the collection method.

Table 4-1. Sensor Data Collection Summary.

Parameter	# Locations	Manufacturer	Model
Level	44	Vega	VEGAPULS C 21
Turbidity	50	Yosemitech	Y511-A
Conductivity / Temperature	50	Yosemitech	Y520-A
Soil Moisture	5 (one per sub-watershed)	Meter	TEROS 12
Precipitation		Texas Electronics	TE525WS-L
Air Temperature + Humidity		Meter	ATMOS 14
Wind Speed		Meter	ATMOS 22
Instantaneous Dissolved Ortho- Phosphate (online chemical analyzer)	10	Green Eyes LLC	Nu-Lab

Table 4-2 shows the approximate monitoring schedule for various parameters.

Table 4-2. Approx. Sensor Deployment Timeline.

Sensor	Jan	Feb	Mar*	Apr	May	June	July	Aug	Sept	Oct	Nov*	Dec
Level	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity			X	X	X	X	X	X	X	X	X	
Temp/Conductivity			X	X	X	X	X	X	X	X	X	
Soil Moisture	X	X	X	X	X	X	X	X	X	X	X	X
Precipitation	X	X	X	X	X	X	X	X	X	X	X	X
Air Temperature + Humidity	X	X	X	X	X	X	X	X	X	X	X	X
Wind Speed	X	X	X	X	X	X	X	X	X	X	X	X
Instantaneous Dissolved Orthophosphate			X	X	X	X	X	X	X	X	X	

Months denoted with an *asterisk* will typically include seasonal installation and removal of Turb, Temp/Cond and Chemical Analyzers (based on weather conditions) thereby potentially reducing the number of days for data collection in these months. Details with respect to the various monitoring methods are included below.

4.1.1 Water Level

Most monitoring locations will be equipped with a wired VEGAPULS C 21 radar sensor (or similar) for continuous water level measurement. This non-contact sensor is designed for measurement in open channels, preventing complications caused by flowing debris during storm events or sensor fouling due to prolonged water contact. At each site, the radar sensor data will be referenced to elevation (*feet above mean sea level*) for reporting purposes. Appendix A includes operating instructions for the VEGAPULS C21.

4.1.2 Turbidity

Most monitoring locations will be equipped with a Y511-A self-cleaning Yosemitech Turbidity sensor, or similar instrument. This optical sensor will be installed at ~ mid depth in the water column. The sensor face is kept clear by an automatic wiper that cleans the instrument prior to each reading. Resolution for the instrument is 5% or 0.3 NTU. The range is 0.1 to 1000 NTU. Appendix B includes the user manual for this instrument.

4.1.3 Conductivity

Most monitoring locations will be equipped with a Y521-A Yosemitech Conductivity sensor, or similar instrument. This sensor will be installed at ~ mid depth in the water column. Accuracy for the instrument is +/- 1%. The range is 1 uS/cm to 100 mS/cm. Appendix C includes the user manual for this instrument.

Figure 4-1 shows a typical installation method for water-contact sensors such as water temperature, turbidity and conductivity at locations where autosamplers and NuLABs will also be deployed. At locations without this additional equipment, water contact sensors may be installed on a post within the creek / drain. The details of specific installations will conform to local conditions.

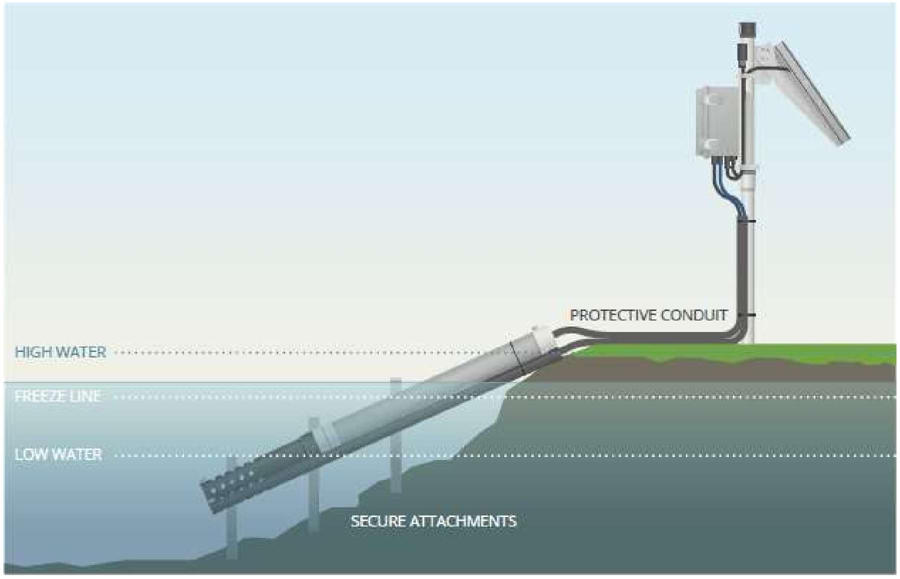

Figure 4-1. Typical In-Water Sensor Installation Method.

4.1.4 Soil Related Parameters

The TEROS 12 sensor will be utilized at (5) locations (one in each sub-watershed) to measure volumetric water content (VWC), temperature and bulk electrical conductivity (EC) in soil. The TEROS 12 will be deployed with a datalogger and cellular modem to provide real-time access to soil data at select monitoring locations. The dielectric measurement frequency of this instrument is 70 MHz. Table 4-3 lists the range, resolution and accuracy achieved by the sensors included. Appendix D includes the user manual for TEROS 12 operation.

Table 4-3. TEROS 12 Sensor Details.

Volumetric Water Content	*The VWC range is dependent on the media the sensor is calibrated to. A custom calibration will accommodate the necessary ranges for most substrates.*		
Range	*Mineral Soil Cal:* 0.00-0.70 m3/m3	*Soilless Media Cal:* 0.0-1.0 m3/m3	*Apparent Dielectric Permittivity (ε_a):* 1 (air) to 80 (water)
Resolution	0.0010 m3/m3		
Accuracy	*Generic Cal:* +/- 0.03 m3/m3 (+/- 3% VWC typical in mineral soils that have solution <8,000 uS/cm	*Medium Specific Cal:* +/- 0.01-0.02 m3/m3 in any porous medium	*Apparent Dielectric Permittivity (ε_a):* 1-40 (soil range) +/- 1 ε_a (unitless) 40-80, 15% of measurement
Temperature			
Range	-40 to 60 °C		
Resolution	0.10 °C		
Accuracy	+/- 0.5 °C from -40 to 0 °C, +/- 0.3 °C from 0 to +60 °C		
Bulk Electrical Conductivity			
Range	0-20,000 uS/cm (bulk)		
Resolution	1 uS/cm		
Accuracy	+/- (5% + 10 uS/cm) from 0-10,000 uS/cm, +/- 8% from 10,000 to 20,000 uS/cm		

4.1.5 Precipitation Measurement

Rainfall will be measured at the (5) locations (one in each sub-watershed) with a Texas Electronics TE525WS-L Rain Gage with 8-inch orifice. Measurements from within the various sub-watersheds will provide added detail to storm events as they pass through the various study areas. The gage is constructed of anodized aluminum, with a tipping bucket sensor and a magnetic reed switch. Appendix E includes the User Manual for TE525WS-L rain gage operation. This rain gage conforms to the National Weather Service recommendation for an 8-inch funnel orifice. Table 4-4 lists the specifications for the TE525WS-L.

Table 4-4. TE525WS-L Rain Gage Specifications.

TE525WS-L Rain Gage	
Operating Temperature Range	0 to 50 °C
Resolution	1 tip
Volume per Tip	8.24 ml / tip
Rainfall per Tip	0.01 inches / tip
Measurement Uncertainty	1.0% up to 2 inches / hour

4.1.6 Air Temperature and Humidity

The ATMOS 14 air temperature and humidity sensor will be utilized for monitoring real-time atmospheric conditions at (5) locations (one in each sub-watershed). Table 4-5 lists the specifications for the ATMOS 14 temperature and humidity sensor. Appendix F contains the user manual for the ATMOS 14.

Table 4-5. ATMOS 14 Specifications.

Relative Humidity	
Range	0 to 100 % RH (0.00-1.00)
Resolution	0.10% RH
Accuracy	see appendix F
Temperature	
Range	-40 to 80 °C
Resolution	0.1 °C
Accuracy	+/- 0.2 °C
Vapor Pressure	
Range	0 - 47 kPa
Resolution	0.01 kPa
Accuracy	see appendix F
Barometric Pressure	
Range	1 - 120 kPa
Resolution	0.01 kPa
Accuracy	+/- 0.05 kPa at 25 °C

4.1.7 Wind Sensor

Air speed at the (5) monitoring locations will be monitored with the ATMOS 22 Ultrasonic Anemometer. Table 4-6 shows the ATMOS 22 sensor specifications. Appendix G includes the user manual for the ATMOS 22.

Table 4-6. ATMOS 22 Specifications.

Horizontal Wind Speed	
Range	0 to 30 m/s
Resolution	0.01 m/s
Accuracy	The greater of 0.3 m/s or 3% of measurement
Wind Gust	
Range	0.00 to 30.00 m/s
Resolution	0.01 m/s
Accuracy	The greater of 0.3 m/s or 3% of measurement
Wind Direction	
Range	0 to 359°
Resolution	1°
Accuracy	+/- 5°
Tilt	
Range	-90 to 90°
Resolution	0.1°
Accuracy	+/- 1°

4.1.8 Nutrient Analyzers

Green Eyes nutrient analyzers will be installed at (10) locations for hourly dissolved Ortho phosphorus measurements. Inside the instrument, surface water, an on-board calibration standard and reagents are mixed by a syringe pump. Once mixed, the reacted solutions are analyzed in a high precision colorimeter. One batch of chemical reagents typically equip an analyzer to provide readings for 6-weeks. It is anticipated that nutrient analyzers will be prepped and verified "ready-for-service" at the office, then rotated in by exchanging it with a deployed unit. Post deployment QA/QC will then be performed on the recently retrieved unit to determine sensor drift, standard degradation, etc. Units will then be prepped to be put back into service at the next rotation.

Table 4-7 provides details with respect to detection limits and Appendix H includes the user manual for the Green Eyes nutrient analyzer.

Table 4-7. Green Eyes Nutrient Analyzer Phosphate Specifications.

Green Eyes Nutrient Analyzer Phosphate Specifications		
Range	High Sensitivity Detector (10mm)	0.006 to 0.8 mg/L
	Low Sensitivity Detector (2mm)	0.025 to 2.0 mg/L
Precision	3%	
Accuracy	Based on the accuracy of the preserved on-board standard and sample replicate precision.	
Analysis Time	16 minutes	

4.2 Sensor Installations- Tile Drain Monitoring

Subsurface tile drains will be monitored at six locations within the priority watersheds to improve knowledge of nutrient source contributions within specific reaches of streams. Locations will measure level, as well as utilize an autosampler to collect total phosphorus, dissolved reactive phosphorus, and nitrate samples. Locations will use a combination of custom-built low-cost sensor devices and research grade equipment., using redundant sensors in some instances for comparison. Table 4-8 outlines the data to be collected, as well as the collection method. Appendix L includes the user manuals for tile drain sensors.

Table 4-8. Sensor Data Collection Summary.

Parameter	Estimated # Locations	Manufacturer	Model
Level (bubbler)	2	ISCO	External TIENet 330
Level (ultrasonic)	6	ELEGOO	HC-SR04
Conductivity, Temperature and Water Level	4	Meter Group	HYDROS 21

4.2.1 Water Level

Most monitoring locations will be equipped with a wired SR-04 ultrasonic sensor (or similar) for continuous water level measurement. This non-contact sensor is designed for measurement in open channels, preventing complications caused by flowing debris during storm events or sensor fouling due to prolonged water contact. Some sites will be paired with redundant sensors, either bubbler flow meters or pressure transducers for comparison of measurements. Table 4-9 shows specifications for sensors used in tile drain monitoring.

Table 4-9. Tile Drain Sensor Specifications.

	Ultrasonic Sensor SR-04	External TIENet 330	HYDROS 21
Operating Frequency	40 KHz	n/a	n/a
Operating Range	2cm ~ 400cm	0.003 to 3.05m (0.01 to 10 ft.)	0 – 10,000 mm
Accuracy	(1in ~ 13ft) ± 3mm	±0.002m @ 22°C (±0.007 @ 72°F)	±0.25% of full scale at 20 °C

Figure 4-2 shows a typical approach to tile drain monitoring.

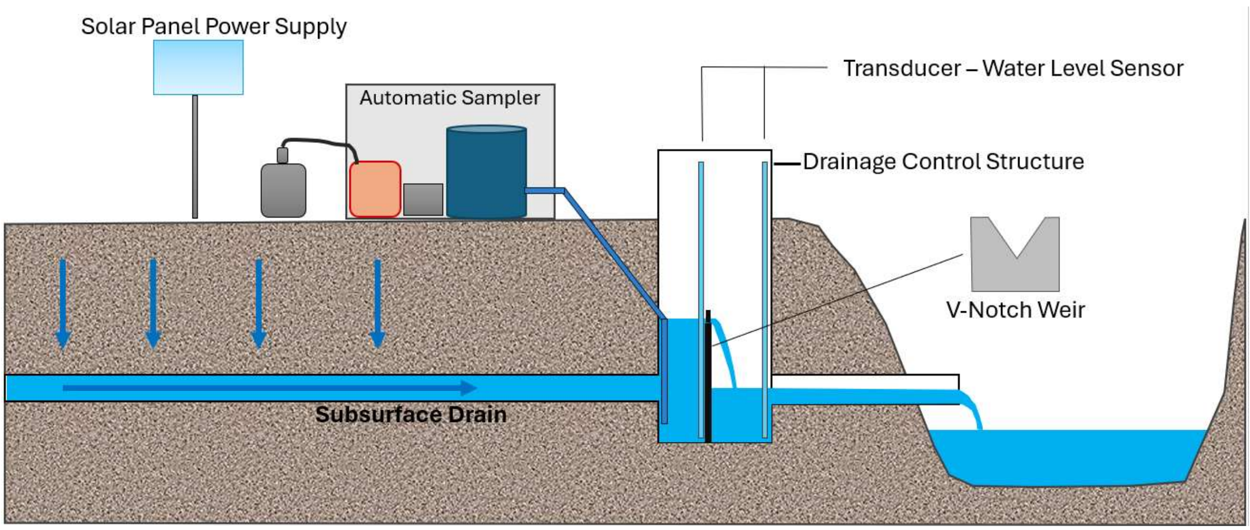

Figure 4-2. Typical Tile Drain Monitoring Approach.

5 MONITORING METHODS- SAMPLE / DATA COLLECTION

5.1 Sensor Data & Sample Collection Strategy

Data from deployed sensors at select locations will be generated as explained in Section 4. Sensor data will indicate when and where precipitation induced periods of runoff are occurring in each subwatershed. A subset of these runoff events will be targeted for sampling to determine how sediment and phosphorus are being transported.

5.2 Sub Watershed Sample Collection Details

Sample collection within the various sub-watersheds will consist of manual grab sampling, as well as the use of remotely initiated automatic samplers at strategic locations. Table 5-1 shows the targeted schedule for sample collection. The installation and removal of in-stream sensors will be dependent on seasonal conditions, likely occurring Feb/March and Nov/Dec. It is anticipated that sampling events will not occur prior to or after the removal of sensors, though opportunities to quantify contributions from extreme runoff events on frozen ground via grab sample (i.e.- Jan/Feb) will be considered. A starting point for the qualification of forecasted rainfall as an “event” will begin at 0.5” of rain over a 24-hour period, but a major factor governing runoff is anticipated to be the local soil’s ability to absorb precipitation. Consideration will also be given to soil moisture values being reported from the subwatershed soil moisture probes and the % stage of subwatershed drainage systems at the time of precipitation. USGS stations will also be referenced to determine if an event will be initiated.

Table 5-1. Target Surface Water Sample Collection Schedule.

<table>
<tr><th>Sampling Event Type</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>June</th><th>July</th><th>Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Grab Events*</td><td></td><td colspan="3">1 (+ 1?)</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="3">1 (+ 1?)</td><td></td></tr>
<tr><td>24-hour, time proportional composite Autosampler Event</td><td></td><td></td><td>1</td><td>1</td><td>1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td></td></tr>
</table>

*The target frequency of grab sampling events will be 4x-6x/monitoring season. Efforts will be made to schedule sample collection to coincide with runoff conditions.

Table 5-2 indicates the type and targeted number of sampling events (ultimately determined by observed conditions) and analytical parameters for collected samples.

Table 5-2. Sample Collection Details.

Sampling Event Type	Sub-Watershed	# Locations	Possible # Events / Year	Duration of Each Event	Analytical Parameters
Annual Grab Event (all sub-watershed locations)	Saline	13	4 to 6	1 day	• Total Phosphorus • Dissolved Reactive Phosphorus • Total Suspended Solids
	S. Br. Raisin	12			
	Niles Ditch	9			
	Lime Creek	11			
	S.S. La Pointe	5			
Time proportional Autosampler Events	Saline	2	Up to 6	Up to 3 days	
	Stony / S. Br. Raisin	3			
	Nile Ditch	2			
	Lime Lake	2			
	S.S. La Pointe	1			

The following sections provide details with respect to sampling.

5.2.1 Grab Sampling & Sample Filtration

Grab sampling will be conducted periodically, with up to (6) events occurring annually, with some likely coinciding with Autosampler events. The timing of sampling initiated in each sub watershed will be dependent on locally monitored real-time conditions including water level, conductivity, turbidity and NuLAB measurements, as well as recent and forecasted precipitation. Efforts will be made to coordinate sample collection at or around hydrograph peaks. However, the logistics of visiting many sites over the course of a day will not allow for peak samples everywhere. Sensor data will allow for the determination of the precise position on the hydrograph where samples were collected. Grab events will be targeted to occur during the following four annual periods:

- 1 (or 2) event(s) between sensor installation in February/March through April,
- 1 event in May/June,
- 1 event in July/August,
- 1 (or 2) event(s) between September and sensor removal in Nov/Dec.

If rainfall / runoff conditions are not widespread throughout the various sub watersheds, sampling may occur in only the sub-watersheds that exhibit favorable runoff/flow conditions for sampling.

Samples will typically be collected from bridges and/or culverts targeting the centroid of flow with a stainless-steel bucket. The bucket may be suspended via a rope, if necessary to reach the water surface. Before sample collection, the bucket will be cleaned with liquinox and either deionized or distilled water. The first three bucketfuls of collected water will be discarded as a rinse. Once collected, the bottle for total suspended solids analysis should be poured off immediately, agitating the bucket as necessary to keep any suspended sediment from settling out. The total phosphorus sample should then be poured off. Finally, the DRP sample should be field filtered within 15 minutes of collection into the sample container using a 0.45 micrometer pore size filter.

Care will be exercised to avoid disturbing the bottom sediments during sampling, as this may introduce non-representative conditions to the water column. Appropriate personal protective equipment, including nitrile gloves, will be worn during the sampling process to avoid cross contamination and/or exposure to bacteriological hazards, such as *E. Coli.* Gloves will be replaced after sample collection at each location.

5.2.2 Auto Samplers

It is anticipated that Teledyne ISCO automatic samplers will be installed at (10) monitoring locations. Auto samplers will be equipped with cellular modems to remotely initiate event sampling. The ISCO 6712 portable sampler (or similar) will be utilized for sample collection. Autosamplers will also be equipped with a refrigerated enclosure to keep collected samples chilled prior to their pickup. Figure 5-1 shows the 6712 model autosampler.

Figure 5-1. ISCO 6712 Portable Auto-Sampler.

Autosamplers will be equipped with a (24) 1L bottle carousel, allowing for samples to be collected at various points over the course of the hydrograph. Auto samplers will be visited approximately 24-hours to 7 days following the initiation of sampling. Sample selection will be based on review of the hydrograph sensor data. At that time, the appropriate bottle(s) will be poured off into sample containers for laboratory analysis. The following steps will be followed at the time of autosampler collection:

1. Upon arrival at the site, the status of the autosampler's program will be noted (i.e.- current bottle # of program, etc.) and if necessary, stopped.

2. Note the length of time stored prior to filtration or preservation.

3. The selected bottle(s) should be removed from the autosampler, capped, and shaken to thoroughly re-suspend any solids captured during sampling.

4. The TSS sample will then be immediately poured off, followed by the Total Phosphorus sample. Sulfuric acid (H_2SO_4) should be added to the sample at this time.

5. Sample will then be filtered for DRP analysis using one of the filtration methods outlined in section 5.1.4.

Once sample bottles are filled and placed on ice, the bottles will either be replaced or cleaned with liquinox and deionized water and reinstalled in the autosampler. If samples were collected prior to the conclusion of the sampling event, the autosampler will be re-initiated.

Refrigerated autosamplers were chosen to reduce sample degradation from the time of collection until filtration / preservation, therefore significantly lowering labor costs for this task. Total phosphorus and dissolved reactive phosphorus (DRP) are critical parameters to monitor with respect to the Western Lake Erie Basin (WLEB), but (especially DRP) has the labor/budget intensive requirement of filtering a sample within 15-minutes of collection.

For the analysis of these parameters from autosamplers used over the course of this project, we seek to build on the research of Heidelburg University, who established that though a statistical difference between DRP samples (fresh vs. stored) exists, most DRP differences were at lower-level concentrations. Stored samples equated to a small, consistent increase in DRP concentration that had no detectable effect on loading estimates. (Roerdink, NCWQR, Heidelburg University. 2022).

Opportunities to test these findings include;

- Long term comparison between autosampler DRP results and hourly NuLAB DRP data (at the same location)

- Long term comparison of autosampler DRP results and grab sample DRP data (with immediate filtration).

- Periodic regional comparisons with USGS data (collection schedule TBD).

5.2.3 Tile Drain Sample Collection

Subsurface tile drains will be sampled based on a flow-paced or time-paced interval based on the discharge curve, site conditions, and other physical characteristics of the drainage area. Table 5-3 shows the sample collection schedule. All samples will be collected with automatic sampling devices. Due to costs and temperature limitations of some sensors, water samples will be collected during months of the year that are less subject to freezing temperatures.

Table 5-3. Tile Drain Target Sample Collection Schedule.

Sampling Event Type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
24-hour composite Autosampler Event			X*	X	X	X	X	X	X	X	X*	

*March and November data collection may be limited depending on the number of days below freezing and any impact these conditions may have on sampling lines or sensors.

5.2.4 Auto Samplers (Tile Drain)

ISCO Teledyne Automatic samplers will be used at four tile drain sampling locations collecting 100 ml of composite sub-surface water samples to fill up to 800 ml in a bottle using the ISCO ProPak bags from the drainage structure or drainage pipe. Constructed low-cost auto samplers will be used at the other two tile drain locations. Figure 5-2 shows the typical equipment to be used during tile drain sampling.

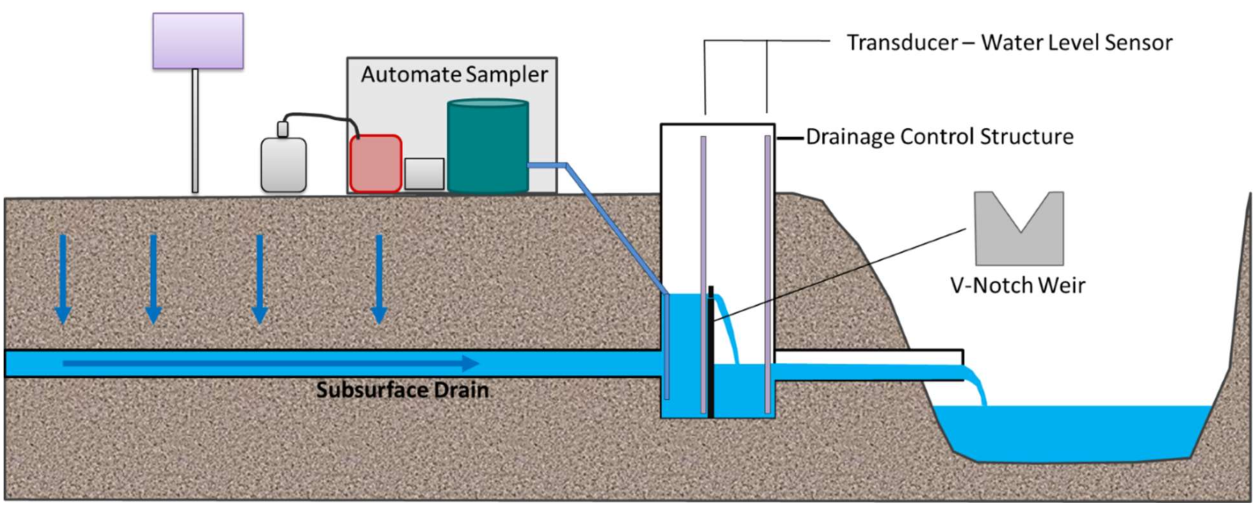

Figure 5-2. Tile Drain Sampling Design for Drainage Control Structures.

5.2.5 Dissolved Reactive Phosphorus (DRP) Sample Filtration

For both tile drain and surface water samples, filtration of the DRP sample should be conducted immediately upon sample collection.

A syringe can be used to push the sample through the filter using positive pressure. Multiple syringes of sample may be required to achieve the appropriate volume necessary for analysis (see Table 5-3 for details). Multiple filters may also be necessary depending on the amount of suspended sediment present in the sample. Figure 5-3 shows a typical low-capacity filter.

Figure 5-3. Whatman 0.45-micron filter.

Figure 5-4 shows a typical syringe to which the Whatman filter is attached for filtration.

Figure 5-4. 50 mL Syringe with Luer Lock Tip.

If excessive suspended solids are observed during sampling, a higher capacity, in-line 0.45-micron filter such as the one shown in Figure 5-5 may be used with a peristaltic pump.

Figure 5-5. Higher Capacity 0.45-micron In-line Filter.

All filters are single use, to be used at one location and discarded. If desired, filtration syringes may be cleaned for re-use using liquinox and deionized water between locations. If cleaned, 50 ml of the new sample should be passed through the syringe as a rinse prior to subsequent filtration.

5.2.6 Sample Analysis and Preservation

Once collected (during grab-sampling) or picked up (from autosamplers), samples will be preserved, filtered and immediately be placed on wet ice and stored at six degrees Celsius until delivery to the analytical laboratory. Analytical samples will be submitted to Michigan State University Department of Biosystems and Agricultural Engineering (BAE) Laboratory. Samples will not be allowed to be submerged under wet ice or melted ice water and will be delivered to the analytical laboratory within the hold time, always maintaining chain of custody. Table 5-4 summarizes details related to sample preservation and preparation.

Table 5-4. Analytical Details.

Parameter	Method	Volume	Preservation	Hold Time
Total Suspended Solids	Standard Methods 2540-D TSS (2017)	Up to 700 ml	Chill to 6^0 C	7 days
Total Phosphorus	Alkaline persulfate digestion-Colorimetric: EPA 365.3	250 ml	6^0 C only if less than 48 hours for lab delivery. 6^0 C + H_2SO_4 for analysis within 28 days.	48 hours to 28 days
Dissolved Reactive Phosphorus (field-filtered)	Colorimetric: EPA 365.3	25 ml	Immediate filtration, chill to 6^0 C	48-hours if chilled, longer if frozen

Laboratory SOPs from the Michigan State University Department of Biosystems and Agricultural Engineering (BAE) Laboratory are included as Appendix I.

5.2.7 Sample Labeling

Sample bottles will be labeled with permanent ink in a manner consistent with the lab requirements and matching the chain of custody. Care will be taken to ensure that duplicates are labeled in a manner consistent with instructions in section 8.1.1. Information on the sample bottle label must include the site identification code and may also include the date and time of sampling, type of analysis, if filtered and the preservation added, if applicable. The sample identifiers on the bottle must match those on the COC form which accompanies the samples.

5.2.8 Chain of Custody

Proper sample handling and custody procedures ensure the custody and integrity of samples beginning at the time of sampling and continuing through transport, sample receipt, preparation, and analysis. The list of items below should be included on the COC form.

- Date and time of collection.
- Site identification.
- Analyses required.
- Name of collector.
- Custody transfer signatures and dates and time of transfer; and
- Name of laboratory admitting the sample.

A sample is in custody if it is in actual physical possession or in a secured area that is restricted to authorized personnel. The COC form is used to document sample handling during transfer from the field to the laboratory and among contractors.

All failures associated with COC procedures are immediately reported to the Field Coordinators. These include such items as delays in transfer, resulting in holding time violations; violations of sample preservation requirements; incomplete documentation, including signatures; possible tampering of samples, broken or spilled samples, etc. The Field Coordinators will determine if the procedure violation may have compromised the validity of the resulting data. Any failures that have reasonable potential to compromise data validity will invalidate data and data from that sampling event should be flagged. The resolution of the situation will be reported to the appropriate Project Manager(s) and corrective actions will be undertaken by the Field Coordinators.

5.2.9 Field Notes

Field notes will be recorded during each sampling event in a manner that documents important information for future reference. Specific observations and documentation to be recorded in the field include the following.

- Sampling dates, times, locations, and IDs.

- Methods of sample collection.
- Flow measurement data (level, velocity, stream width, equipment used, etc.)
- Personal encounters at monitoring locations and what was discussed (i.e.- property owners, Road/Drain commission, State of Michigan personnel, concerned citizens, etc.)
- General water characteristics (sonde measurements, observations).
- Field conditions or recent field management (manure application, tillage, fertilization application, harvest, etc.)
- Assessment of the integrity of, and/or maintenance needed with respect to equipment installations at a monitoring location.

Additional observations may include;

- Photos of sample locations during various runoff conditions.
- Notable weather observations
- Anything out of the ordinary and/or of interest to the project.

5.3 Sub Watershed In-Situ Data Collection

During sampling, measurements will be collected with respect to in- situ water parameters and river/creek discharge. The following sections provide details with respect to data collection.

5.3.1 In-Situ Sonde Measurements

In situ measurements of temperature, dissolved oxygen, specific conductance, turbidity, and pH will be collected at every site a with multiparameter sonde. Measurements will be collected at mid-depth in the water body, in an area where flow is representative of the site (avoiding stagnant areas). During measurements taken in low water (i.e., <1'), care will be taken to collect representative data of the creek or drain. If it is not feasible to do so, it will be noted, and a sample should not be collected at that location either.

All instruments used for *in situ* measurements will be calibrated (with documentation) according to manufacturer instructions and SOPs (Appendix J).

Sonde measurements will be recorded at the time of sample collection during rounds of grab sampling and autosampler collection. Sondes will be calibrated prior to use and a record of the calibration will be saved. Sondes will also be checked and/or post-calibrated upon returning to the office to quantify instrument drift throughout the day that could result from a faulty sensor. Parameters to be recorded and acceptable ranges of sensor drift are included in Table 5-4.

Table 5-5. In-Situ Parameters.

Parameter	Instrument	Range	Accuracy	Resolution	Acceptable Sensor Drift at Post-check
Temperature	YSI EXO (or equivalent)	-5 to 50°C	+/- 0.2°C	0.001°C	n/a
pH		0 to 14 units	+/- 0.1 pH units within +/- 10°C of calibration temperature, +/- 0.2 pH units for entire temperature range.		In 7.0 buffer: 6.65 to 7.35
Dissolved Oxygen		0 to 500% air sat, 0 to 50 mg/L	0-200%: +/- 1% reading or 1% air sat, whichever is greater. 200-500%: +/- 5% reading. 0-20 mg/L: +/- 1% of reading or 0.1 mg/L, 20-50 mg/L: +/-5% reading.	0.1% air sat., 0.01 mg/L	Within 5% of saturated value
Conductivity (as Specific Conductance)		0-100,000 uS/cm	+/- 1% of reading or 2 uS/cm, whichever is greater	0.0001 to 0.01 mS/cm range-dependent	Within 5% of Cal Standard (+/- 50 uS/cm)
Turbidity		0 to 4000 FNU	0-999 FNU: 0.3 FNU or +/- 2% of reading, whichever is greater. 1000-4000 FNU: +/- 5% of reading.	0-999 FNU: 0.01 FNU, 1000-4000 FNU: 0.1 FNU	Within 5% of Cal Standard (+/- 4 NTU)

5.3.2 Flow/Discharge Measurements

Periodic discharge measurements will be collected at all sites (except sites co-located at a USGS gage station) over the course of the study period to develop a rating curve to generate continuous flow from recorded level readings. The cross section of the creek will be subdivided into bins, with the depth, width and water velocity of each bin recorded/measured. The more bins that a stream is divided into, the more accurate the discharge measurement. Regardless of the method used, the parameters of streamflow will be quantified in a manner consistent with that displayed in Figure 5-8.

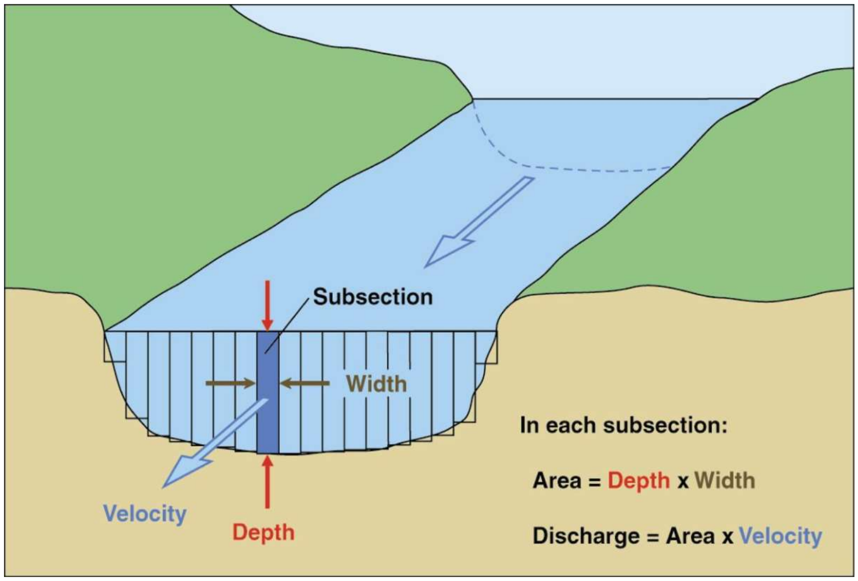

Figure 5-6. Discharge Data Collection Approach.

For manual measurements conducted on small drains, the stream channel should be subdivided into ten measurements, if feasible, putting no more than 10% discharge on one measurement. At shallow, wadable sites, streamflow will be measured using a Hach MF Pro (or equivalent) and a wading rod. In water less than 1.5' deep, (1) velocity measurement at 60% of the total depth will be collected. For stream depths >1.5', (2) measurements should be taken; (1) at 20% depth (i.e.- down from the surface) and (1) at 80% depth. Figure 5-6 shows the MF Pro and wading rod.

Figure 5-7. OTT MF Pro Flowmeter and Wading Rod.

Appendix K, a Standard Operating Procedure document for Surface Water Flow Measurements, contains simplified instructions for conducting discharge measurements while wading.

At deeper, non-wadable locations, flow will be measured using a Sontek M9, or similar.

Figure 5-7 presents a Sontek RiverSurveyor M9 ADCP.

Figure 5-8. Sontek RiverSurveyor M9 ADCP.

For discharge measurements on larger creeks and rivers using the Sontek M9, the software automatically subdivides the stream channel into > 20 bins, meeting USGS recommendations. The Sontek M9 is controlled by and sends data to an operator's laptop wirelessly via Bluetooth. Once (2) to (4) passes across the channel are performed that result in a discharge of +/- 10%, the measurement can be concluded.

5.3.3 Tile Drain Data Collection

In addition to instrumented data collection occurring through sensors and automatic samplers, where conditions are applicable (safe from flooding/submergence), cameras will be used to observe water stage data being discharged from the tile drains. At each sample collection visit (if tiles are not submerged) three timed water flow measurements will be collected using appropriately sized containers (based on flow rate) at the end of the pipe and combined for an average flow rate. These measurements will be added to the field notes and compared weekly to instrumented flow measurements.

6 DATA PROCESSING & MANAGEMENT

6.1 Level vs. Discharge Relationship

Flow measurements will be collected around the peak discharge at a location as frequently as feasible. Over the course of the study, measurements from each of the 0-50%, 50-75% and 75-100% discharge will be targeted to populate the level to discharge rating curve. Opportunities to measure / quantify flow conditions are anticipated to occur during site visits outlined in Table 6-1. On (up to) three occasions per year, teams may be dispatched for the sole purpose of measuring flows during high flow periods (75% to 100% peak), if necessary.

Table 6-1. Annual Opportunities for Flow Measurements.

Reason for Site Visit	Max # visits annually	% Peak Discharge Anticipated During Station Visits		
Level + Turbidity + Temp/Conductivity (Only) (38 locations)		**1-50%**	**50-75%**	**>75%**
Level sensor verification, turbidity/conductivity sensor check, general site maintenance =	***5***	4	1	
Grab sampling events (up to) =	***6***	2	2	2
High flow response measurements =	***3***			3
Possible # Flow Measurements =	***14***	***6***	***3***	***5***
Level + Turbidity + Temp/Cond + NuLAB + Autosampler (8 locations)		**1-50%**	**50-75%**	**>75%**
Level sensor verification, turbidity/conductivity sensor check, general site maintenance =	***5***	4	1	
NuLAB rotation changeout =	***5***	4	1	
Grab sampling events (up to) =	***6***	2	2	2
Wet weather sample collection/redeployment (possible 6 events, each lasting up to 3 days) =	***18***	6	6	6
High flow response measurements =	***3***			3
Possible # Flow Measurements =	***37***	**16**	**10**	**11**

To ensure the streamflow estimates derived from the continuous water level sensor data and stage-discharge curves are reasonable, a cumulative flow volume will be computed for each site, divided by the drainage area to each site to result in a “per-unit-area streamflow yield”. These values will be compared against the same cumulative streamflow yield for the same combined period at monitoring locations further downstream, including any USGS gaging stations, if available.

6.1.1 Turbidity / TSS Relationship

Turbidity data will be continuously collected by deployed Yosemitech sensors at many of the monitoring locations. In addition, turbidity measurements will be acquired via handheld EXO sonde during sampling visits at the same monitoring locations. The accuracy of both sensors will be quantified by calibration procedures using turbidity standards. The comparison of measurements by these two instruments occurring at the same time and location will allow for a determination of precision within turbidity measurements collected during the project.

Over the course of the project, samples will be collected for Total Suspended Solids (TSS) analysis. A relationship between TSS analytical data and sensor-based turbidity measurements will be developed to facilitate a better understanding of TSS movement throughout the study area. Auto samplers are planned to collect composite samples over 24-hour periods and therefore will not have an individual turbidity measurement to associate with a TSS value. These comparisons will be obtained during grab sample collection. Table 6-2 shows the number of possible comparisons anticipated during one year of sampling.

Table 6-2. Possible Annual Turbidity vs. TSS Comparison Points.

Sampling Event Type	Sub-Watershed	# Locations	Possible # Events / Year	Duration of Each Event	Possible Annual Turbidity / TSS Comparisons
Annual Grab Event (all sub-watershed locations)	Headwaters Saline River	13	4 to 6	1 day	78
	S. Br. Raisin	12			72
	Nile Ditch	9			54
	Lime Creek	11			66
	S.S. La Pointe	5			30

6.1.2 Rating Curve Development

For the relationships of both “Level to Discharge” and “Turbidity to TSS”, a rating curve will be developed to determine the accuracy of estimation between the two data sets. An example of such a relationship has been included as Figure 6-1.

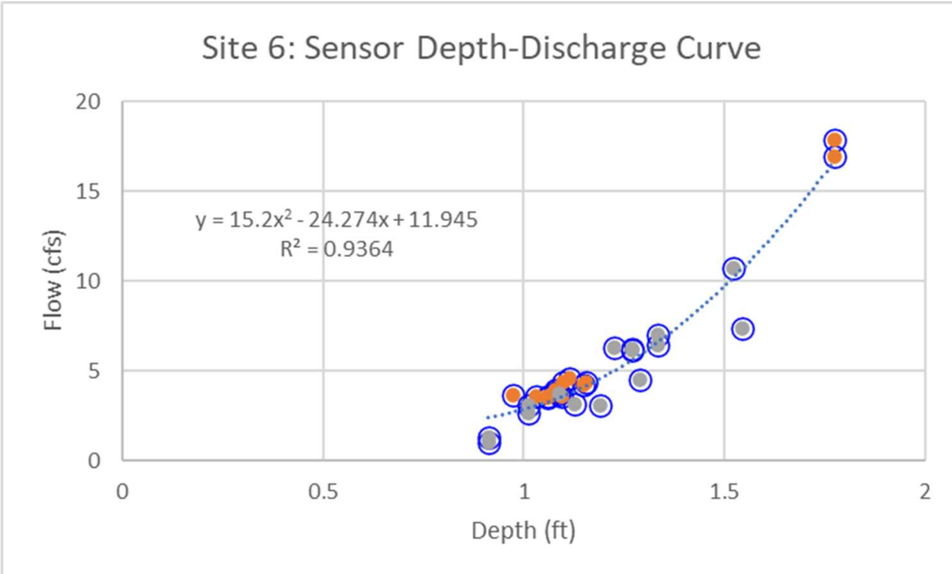

Figure 6-1. Example of Rating Curve.

6.1.3 Data Dashboard

Sensors installed in the field will be connected to an onsite datalogger and cellular modem, allowing for real-time transmission of data to an internal (non-public) data dashboard. The dashboard will allow project personnel to verify the continued functionality of all deployed sensors, as well as observe hydraulic conditions and trends as they progress through the various sub watersheds. Sensor data will undergo various QA/QC checks, including the following:

- Comparisons between sensor data and field measurements conducted at the same time and location during site visits.
- Accuracy verification of deployed sensor data using pre/post sensor checks and/or calibrations performed in the field. (i.e.- water level, water temp, conductivity, turbidity)
- Data found to be outside of acceptable calibration range (i.e.- 5%) will be flagged and the cause for variation investigated.

7 QUALITY CONTROL- SENSOR DATA

Collecting reliable sensor data depends on maintaining instruments in clean condition and within their calibrated range. This section outlines how the various sensors used in the project will be maintained.

7.1.1 Level Measurement Verification

The VEGAPULS C21 uses line-of-site radar to measure the distance between the sensor and the first object that it encounters. Quality control procedures and observations with respect to assuring the accuracy of level measurements should include the following;

- Visual /signal return verification that no obstructions exist between the sensor face and the water surface. If so, any obstruction (i.e.-accumulated branches, logs, etc.) will be removed.
- The integrity of the sensor mount remains solid.
- A manual measurement from the sensor face to the water surface should be conducted periodically for comparison to radar data.
- Notation of any recent waterway alterations that would affect the stage to discharge relationship, such as addition or removal of impoundments (debris, animal or manmade), dredging, etc.

7.1.2 Turbidity Measurement Verification

The accuracy of individual turbidity sensors will be verified up to 5 times per year, generally once within a 6-week period. During site visits, quality control procedures with respect to turbidity monitoring should include;

- A side-by-side reading using a calibrated sonde equipped with a Turbidity probe. Ensure that the turbidity sensor was calibrated prior to use.
- Visual inspection and cleaning of the sensor face to remove any accumulated silt or mud.
- Check the integrity of the sensor wiper. If worn, replace as necessary.
- Checking the measurement accuracy of the turbidity sensor in zero, 126 and/or 1000 NTU standard.
- Performing a turbidity calibration of the instrument if the accuracy check / sonde comparison indicates the need for one (>25% disagreement with a calibrated sonde in a bucket of representative, turbid water).

If the quality of data from a particular sensor is suspect, the sensor should be removed from service and replaced.

7.1.3 NuLAB Measurement Verification

The accuracy of measurements provided by the Nu-LAB Green Eyes nutrient analyzer are dependent on many factors, including the integrity of the onboard calibration standard, operating temperatures, potential for fouling, duration of filter use, etc. NuLAB Measurements will be verified using the following steps.

- Periodic laboratory verification of the onboard calibration standard (i.e.- at the time of deployment and retrieval).

- Split sampling- collection/analysis of a grab sample at the same time as a NuLAB reading for comparison.
- Running periodic equipment blank samples on the nutrient analyzer.

8 QUALITY CONTROL- FIELD SAMPLES & LABORATORY PROCEDURES

All surface water samples collected during the project will be analyzed by Michigan State University Laboratory. Analyses will be conducted in accordance with the various lab SOPs included in Appendix J. Analytical results will be reported to Chris Behnke at LimnoTech. All laboratory data provided to LimnoTech will undergo a 100% QC review by Michigan State University Laboratory prior to being reported.

Table 8-1 outlines the data quality indicators for laboratory analyzed samples.

Table 8-1. Project Data Quality Indicators.

		PRECISION		SENSITIVITY		COMPLETENESS
Parameter	**Analytical Method**	**Field Duplicates**	**Matrix Spike Duplicates**	**Method Detection Limit (mg/L)**	**Reporting Limit (mg/L)**	**Criteria**
Total Phosphorus	EPA 365.3	</= 30%	</= 20%	TBD	0.013	95%
Dissolved Reactive Phosphorus (field-filtered)	EPA 365.3	</= 30%	</= 20%	TBD	0.013	95%
Total Suspended Solids	SM 2540 D TSS (2017)	</= 30%	</= 20%	TBD	1	95%

A mixture of laboratory and field variables may affect data quality. The variables include sample matrix variability, sample collection/handling procedures and equipment, sample analysis techniques and record keeping. To control these variables, the Data Quality Objective (DQO) process is used. DQOs developed for this project specify discrete parameters in six areas: Precision, Accuracy, Representativeness, Comparability, Completeness and Sensitivity (PARCCS). A brief description of each of these parameters is presented below, along with the formulas for calculation of precision, accuracy, and completeness for the scheduled analyses.

Precision and completeness are expressed and evaluated quantitatively. Representativeness, accuracy, comparability, and sensitivity are more subjective in nature and are addressed in both quantitative and qualitative terms. The primary QA objective is to measure the quantity of target analytes in each sample without unacceptable bias. Table 8-2 outlines the criteria for acceptable bias.

Table 8-2. Criteria for Acceptable Bias in Analytical Samples.

		BIAS		
Parameter	**Analytical Method**	**Lab Control Samples**	**Matrix Spikes**	**Blanks**
Total Phosphorus	EPA 365.3	90-110%	90-110%	< Reporting Limit
Dissolved Reactive Phosphorus (field-filtered)	EPA 365.3	90-110%	90-110%	< Reporting Limit
Total Suspended Solids	SM 2540 D	90-110%	90-110%	< Reporting Limit

8.1 Field Sampling Quality Control Requirements and Acceptability Criteria

The field staff should complete a documented review of 100% of the field data for compliance with QC requirements, and the QA Officer (or a qualified designee) will complete a review of a minimum of 10% of the field data. Specific requirements are outlined below. Field QC samples are reported with the data report. Field sampling QC consists of collecting field QC samples to help evaluate conditions resulting from field activities. Field QC is intended to support several data quality goals:

- Combined contamination from field sampling through sample receipt at the laboratory (to assess potential contamination from ambient conditions, sample containers, sample transport, and laboratory analysis) – assessed using field or equipment blanks.
- Combined sampling and analysis technique variability, as well as sample heterogeneity – assessed using field duplicates.

8.1.1 Field / Equipment Blanks

A field blank is a sample of reagent water poured into a sample bottle while on-site collecting samples. An equipment blank is a sample of reagent water that has passed through or poured over sample collection equipment. It is collected in the same type of container as the environmental sample, preserved in the same manner and analyzed for the same parameter. These blanks document that the field collection methods by field staff are not contaminating samples, and that decontamination procedures are adequate.

The analysis of field/equipment blanks should yield values less than the detection limit. Blanks that come back with detectable levels indicate that contamination has occurred and the results for that sampling trip are not valid (for all sites represented by the blank). Blank samples should be collected and analyzed for all analytes at a frequency of at least 5% (1 in 20 regular samples). It is recommended that deionized water be used for blank samples.

8.1.2 Precision (Field Duplicates)

Field duplicate samples will be collected at a frequency of at least 10% to evaluate the precision of sample collection through analysis. Field duplicates will be collected at designated sample locations by filling two distinct sample containers for each analysis. The following calculation to determine “Relative Percent Difference” (RPD) can be used to evaluate analytical precision.

Step 1: Calculate RPD using the following formula:

$$RPD = \frac{|C_A - C_B|}{0.5(C_A + C_B)} \times 100$$

If the result of the RPD comparison is < 50%, the duplicate variation is considered acceptable. Duplicate samples should be collected and analyzed for all the analytes at a frequency of at least 10% (1 in 10 regular samples).

8.2 Laboratory Measurement Quality Control Requirements and Acceptability Criteria

Detailed laboratory QC requirements are contained within each individual method and laboratory QA manuals. The minimum requirements that all participants abide by are stated below. Lab QC sample results are reported with the data report.

In addition to regularly collected field blanks, laboratory equipment blanks are prepared at the laboratory where collection materials are cleaned between uses.

Method Blank - A method blank is an analyte-free matrix to which all reagents are added in the same volumes or proportions as used in the sample processing and analyzed with each batch. The method blank is carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination from the analytical process. The analysis of method blanks should yield values less than the Minimum Analytical Level. For very high-level analyses, a blank value should be less than 5% of the lowest value of the batch.

8.3 Accuracy

Accuracy measures the bias in a measurement system. Accuracy of sonde data will be assured by calibrating the sonde daily, per the manufacturer's instructions. If a dissolved oxygen measurement at a site is below 4 mg/L on the first reading (a potential violation of the water quality standard for warm water fish), the dissolved oxygen sensor will be recalibrated on-site, and a repeat measurement will be taken (all data will be reported).

8.4 Representativeness

Representativeness is an expression of the extent to which measured data accurately represents actual conditions. The objective of this sampling effort is to collect samples that accurately represent conditions in the field. The careful design of the sampling plan is of paramount importance in ensuring that the data are representative of prevailing conditions. The sampling plan specifies the number and location of samples to be collected.

The key factors considered in the design of the sampling plan included: (1) providing a sufficient number of samples, and (2) sufficient spatial distribution of samples to ensure that the target area is covered.

Finally, representativeness is dependent on using appropriate sample collection, handling and analysis procedures. These procedures are described elsewhere in this document.

8.5 Completeness Goals and Corrective Actions

Every effort will be made to obtain valid data for each sampling location at all times. Completeness will be measured by dividing the number of planned usable sample results by the total number of sample results. The completeness objective for this project is for 100% of the planned data to be usable (samples collected and analyses generated within the established control limits for precision and accuracy). Completeness is calculated as:

$$\%C = (V/T) \times 100\%$$

Where:

V = Number of measurements judged valid

T = Total number of samples analyzed

Field Coordinators will maintain close communication with Project Managers in order to make any necessary adjustments to the sampling schedule and/or locations, or any other aspects of the study. All staff (field and laboratory) are responsible for providing proper notifications of anything that may necessitate any such adjustments.

8.6 Comparability

Sample collection methods, holding times, sample preservation and laboratory analysis methods will all be conducted in accordance with specified standard methods and protocols. The object is to facilitate observations and conclusions that can be directly compared with historical and/or available background data.

8.7 Sensitivity

Sensitivity is a term broadly applied to the minimum detection capabilities of the specified methods of analysis and instruments used to conduct the scheduled analyses. Minimum detection limits and practical quantitation limits must be established to assure that the selected method of analysis is sensitive enough to detect and quantify concentrations for the parameters of interest. The method description provides a discussion of the Method Detection Limits (MDLs) for the procedure. These limits have been reviewed and judged to be adequate for the purposes of this study. Another variable that may affect sensitivity is holding time. Each analytical procedure has a designated maximum holding time from the point of sample collection to extraction and analysis in the laboratory. The maximum holding time for each analytical parameter is listed in the corresponding method’s specific SOP.

Adequate sensitivity in the project data will be verified through a comparison of the reported Practical Quantification Limits (PQL) after analysis to those in the method’s SOPs. Holding times will likewise be compared to the maximum time specified in each method specific SOP.

9 REPORTING

The Project Managers will report collected data in the following manner:

- Producing twice yearly data analyses and summaries describing observed trends / conditions, delivered in July (previous winter/spring) and January (previous summer/fall).
- Meeting twice yearly with the Executive Office of the Governor, and Executive Offices of MDARD, EGLE and DNR to discuss data analyses and summaries.
- Meeting quarterly with MDARD, EGLE and DNR Division/Bureau staff to provide technical updates on project status and implementation.
- Coordinate the completion of an End of Project Data Summary.

10 REFERENCES

U of M School for Environment and Sustainability & MDARD. 2024, Stony Creek (South Branch River Raisin) Watershed Conservation Plan; **https://deepblue.lib.umich.edu/bitstream/handle/2027.42/192875/AcceleratingWatershedPlanningMDARD_Watershed_Conservation_Plan.pdf?sequence=3&isAllowed=y**

Roerdink, Aaron, National Center for Water Quality Research, Heidelburg University. 2022, Water Quality in Ohio Rivers and Streams, Project Study Plan. **Microsoft Word - NCWQR Study Plan 20220927**

USGS, 2010. Techniques and Methods, Chapter 3- A8. **https://pubs.usgs.gov/tm/tm3-A8/tm3a8.pdf**

11 WORK PLAN ACKNOWLEGEMENT

This Work Plan has been reviewed by the following persons (signatures):

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Michelle Selzer (Project Manager) – MDARD Date

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Tom Zimnicki (Project Manager) – Alliance for the Great Lakes Date

____

Jeremiah Asher (Project Manager) – IWR Date

____

Ed Verhamme (Project Manager) – LimnoTech Date

____

Caroline Keson (Advisory Board) – EGLE Date

____

Ahsan Ghane (Lab QA/QC Supervisor) – MSU Bio/Ag/Eng. Lab Date

APPENDIX A: SOP FOR VEGAPULS-C21 LEVEL SENSOR (VEGA)

APPENDIX B: SOP FOR TURBIDITY SENSOR Y511-A (YOSEMITECH)

APPENDIX C: SOP FOR TEMP/COND SENSOR Y520-A (YOSEMITECH)

APPENDIX D: SOP FOR TEROS 12 SOIL MOISTURE, ELECTRICAL CONDUCTIVITY AND TEMPERATURE SENSOR (METER)

APPENDIX E: SOP FOR TE525 TIPPING BUCKET RAIN GAGE (CAMPBELL SCIENTIFIC)

APPENDIX F: SOP FOR ATMOS 14 AIR TEMP/RELATIVE HUMIDITY SENSOR (METER)

APPENDIX G: SOP FOR ATMOS 22 ULTRASONIC WIND SENSOR (METER)

APPENDIX H: SOP FOR NULAB ONLINE NUTRIENT ANALYZER (GREEN EYES)

APPENDIX I: SOPS FOR LAB ANALYSES OF TOTAL PHOSPHORUS, DISSOLVED REACTIVE PHOSPHORUS AND TOTAL SUSPENDED SOLIDS (MICHIGAN STATE UNIVERSITY)

APPENDIX J: SOP FOR IN-SITU WATER QUALITY MEASUREMENT (LIMNOTECH)

APPENDIX K: SOP FOR IN-SITU DISCHARGE MEASUREMENT (LIMNOTECH)

APPENDIX L: SOPS FOR DRAIN TILE MONITORING EQUIPMENT (MICHIGAN STATE UNIVERSITY)